

## Technical Evaluation Report

**Peter Werkhoven**

TNO Defense, Security & Safety  
Schoemakerstraat 97  
2600JA Delft  
THE NETHERLANDS

[Peter.werkhoven@tno.nl](mailto:Peter.werkhoven@tno.nl)

### 1.0 INTRODUCTION

#### 1.1 Background

Recent improvements in computer systems and displays have enabled new simulation technologies such as Augmented, Mixed, and Virtual Environments (AMVE). Increased computer power at low cost, wireless networks, miniaturizations of sensor and computer components, and better visual, auditory and tactile display systems are contributing to the maturation of these technologies. Potential applications in military operations, as well as training and system design are providing requirements that have spurred this technology development.

Today, most of the attention is focused on the development of the technologies themselves. However, to be effective in military operations, the technologies must evolve into systems that provide the information that their human users need to accomplish military objectives. Compared to research on computer architectures, communication protocols, and display devices there has been relatively little research on the perceptual requirements for displays, human-computer-interaction issues, design of effective training approaches, measurement of human performance and cultural and organizational issues. The fundamental knowledge available today already indicates a large potential of AMVE technology for a broad spectrum of military applications.

An important outcome of a previous workshop “What is essential for Virtual Reality systems to meet military human performance goals” of the NATO Research Study Group HFM-021 in the year 2000 was that:

- baseline applications of VR were solid in the automotive industry and entertainment industry, and military applications were *beginning to emerge* and be evaluated,
- Successful application of VR depends strongly on
  - the quality of the interaction methods of humans with VR (train like we fight),
  - on the on the level of *fidelity* of the virtual world, and
  - on the multidisciplinary involvement of scientists, engineers, practitioners and *users*.

This workshop titled “Virtual media for military applications” organized by the NATO Research Study Group HFM-136 focused on the broader set of AMVE technology for military applications. Military users were brought together with academic researchers and industry to discuss if AVME meets operational needs. It provided a unique opportunity to assess advances in AMVE technology and to monitor the progress of the recommended role of human factors research and user involvement in the development of AMVE applications.

| Report Documentation Page                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                                    |                                     |                                            | Form Approved<br>OMB No. 0704-0188          |                                    |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------|-------------------------------------|--------------------------------------------|---------------------------------------------|------------------------------------|
| Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. |                                    |                                     |                                            |                                             |                                    |
| 1. REPORT DATE<br><b>01 JUN 2006</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                    | 2. REPORT TYPE<br><b>N/A</b>        |                                            | 3. DATES COVERED<br><b>-</b>                |                                    |
| 4. TITLE AND SUBTITLE<br><b>Technical Evaluation Report</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                    |                                     |                                            | 5a. CONTRACT NUMBER                         |                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                                            | 5b. GRANT NUMBER                            |                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                                            | 5c. PROGRAM ELEMENT NUMBER                  |                                    |
| 6. AUTHOR(S)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                    |                                     |                                            | 5d. PROJECT NUMBER                          |                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                                            | 5e. TASK NUMBER                             |                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                                            | 5f. WORK UNIT NUMBER                        |                                    |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br><b>TNO Defense, Security &amp; Safety Schoemakerstraat 97 2600JA Delft THE NETHERLANDS</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                    |                                     |                                            | 8. PERFORMING ORGANIZATION<br>REPORT NUMBER |                                    |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                                    |                                     |                                            | 10. SPONSOR/MONITOR'S ACRONYM(S)            |                                    |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     |                                            | 11. SPONSOR/MONITOR'S REPORT<br>NUMBER(S)   |                                    |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT<br><b>Approved for public release, distribution unlimited</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |                                    |                                     |                                            |                                             |                                    |
| 13. SUPPLEMENTARY NOTES<br><b>See also ADM002024., The original document contains color images.</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                    |                                     |                                            |                                             |                                    |
| 14. ABSTRACT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                    |                                     |                                            |                                             |                                    |
| 15. SUBJECT TERMS                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |                                    |                                     |                                            |                                             |                                    |
| 16. SECURITY CLASSIFICATION OF:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                    |                                     | 17. LIMITATION OF<br>ABSTRACT<br><b>UU</b> | 18. NUMBER<br>OF PAGES<br><b>14</b>         | 19a. NAME OF<br>RESPONSIBLE PERSON |
| a. REPORT<br><b>unclassified</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | b. ABSTRACT<br><b>unclassified</b> | c. THIS PAGE<br><b>unclassified</b> |                                            |                                             |                                    |

### 1.2 Purpose and scope of this workshop

Chairman Thomas Alexander pointed out that the purpose of this workshop was:

- to summarize previous and on-going research (and see if AMVE technology indeed provides the intuitive human-system interaction expected),
- to identify the keys for implementation of ready to use technology,
- to identify knowledge gaps and thrusts and establish an agenda for future efforts that explore the human dimensions of virtual media for military applications.

The workshop concentrated on the following research area's:

- Training methods,
- Human performance requirements,
- Performance measurement techniques and assessment,
- Human Factors issues in design and utilization.

with a focus on the following application area's:

- Command, Control, Communication, Computer, Information, Surveillance and Reconnaissance (C4ISR) systems, in particular user interface issues,
- Tele-presence, tele-operation, and tele-manipulation in reconnaissance, surveillance, and target acquisition,
- military training and simulation,
- mission preparation and rehearsal,
- systems acquisition,
- mission support (maintenance, decision aiding, logistics, navigation).

### 1.3 Program workshop

The workshop took place over three days with the following structure:

#### Tuesday, June 13, 2006

- Keynote Address by professor Paul Milgram (Toronto University, Canada): How the concept of Mixed Reality Encompasses Augmented Reality and Virtual Environments.
- Session 1: Command and Control
  - Chairs: Thomas Alexander (Research Establishment for Applied Sciences FGAN, Germany) and Patrik Lif (Swedish Defence Research Agency FOI, Sweden).
  - Speakers:
    - Thomas Alexander (FGAN, Germany): Applicability of Virtual Environments as C4ISR.
    - Jared Freeman (Aptima Inc. US): Measuring, Monitoring, and Managing Knowledge in Command and Control Organizations.

- James Lussier (US Army Research Institute, US): Components of Effective Learning.
- Neville A. Stanton (Brunel University, UK): Experimental Studies in a Reconfigurable C4 Test-bed for Network Enabled Capability.
- Andreas Tolk (Virginia M&S Center, US): Challenges and Potential of Service-oriented Architectures for Net-Centric Operations.
- Hendrik-Jan van Veen (TNO Defense, Security and Safety, The Netherlands): SIMNEC, research platform for studying human functioning in NCW.
- Session 2: Tele-operations
  - Chairs: Ebb Smith (Defence Science and Technology Laboratory DSTL, UK) and Professor Robert Stone (University of Birmingham and Director of the Human Factors Integration Defence Technology Centre (HFI DTC)).
  - Speakers:
    - Robert J. Stone (University of Birmingham, UK): Serious Gaming Technologies Support Human Factors Investigations of Advanced Interfaces For Semi-autonomous Vehicles.
    - Jan B.F. van Erp (TNO Defense, Security and Safety, The Netherlands): Tele-presence: Bringing the Operator Back in the Loop.
    - Michael Barnes (US Army Research Institute, US): Understanding Soldier Robot Teams in Virtual Environments.
    - Boris Trouvain (FGAN-FKIE, Germany): Tele-operation of Unmanned Vehicles, The Human Factor.
    - Robert Taylor (DSTL, UK): Human Automation Integration for Supervisory Control of UAVs.

**Wednesday June 14, 2006**

- Keynote Address by COL James Shufelt (US Army, TRADOC program Integration Office): The Future Role of Virtual Simulators/Simulations in U.S. Army Training.
- Session 3: Vehicle simulation
  - Chairs: Lochlan Magee (DR&D, Canada) and Sylvain Hourier (IMASSA, France).
  - Speakers:
    - LTC Wil Riggins (US Army, Program Executive Office, Simulation, Training and Instrumentation): Requirements for Virtual Vehicle Simulation.
    - Leonhart Vogelmeier (EADS, Military Aircrafts): Interaction Method for Virtual Reality Applications.
    - Brian Schreiber (US Air Force Research Lab and Lumir Research Institute, Arizona ): Evaluating Mission Training Fidelity requirements, Examining key Issues in Deployability and Trainability.
    - Bernd de Graaf (TNO Defense, Security and Safety, The Netherlands): Military Simulation Centre: Vehicle for Validation of Military Flight Simulation.

## Technical Evaluation Report

---

- Mark Espanant (CAE, Canada): The Application of Simulation to Study Human Performance Impacts of Evolutionary and Revolutionary Changes to Armored Vehicle Design.
- Session 4: Dismounted Simulation
  - Chairs: Nico Delleman (TNO Defense, Security and Safety, The Netherlands) and LtCmdr Joseph Cohn (Naval Research Laboratory, US).
  - Speakers:
    - Phillip Jones (MYMIC Low Liability Company, US): Emerging Requirements for Dismounted Virtual Simulators.
    - Amela Sadagic (MOVES Institute, US Naval Postgraduate School): Combined Arms Training, Methods and Measures for a Changing World.
    - Bruce Knerr (US Army Research Institute, US): Current Issues in the Use of Virtual Simulations for Dismounted Soldier Training.
    - Frederick P. Brooks, Jr. (University of North Carolina, US): Challenges of Virtual Environment Training of Dismounted Teams.
    - James Templeman (Naval Research Lab, US): Immersive Simulation to Train Urban Infantry Combat.
    - John Frim (DR&D, Canada): Use of the Dismounted Soldier Simulator to Corroborate NVG Studies in a Field Setting.
- Keynote Address by Bowen Loftin (Texas A&M University, US): The Future of Simulation.

### Thursday June 15, 2006

- Session 5: Mixed and Augmented Reality.
- Chairs: Stephen Goldberg (US Army Research Institute, US) and Lisbeth Rasmussen (Danish Defense Research Establishment, Denmark).
- Speakers:
  - Mark A. Livingston (Naval research Lab, US): Battlefield Augmented Reality.
  - Jarrell Pair (University of Southern California, Institute for Simulation and Training, US): Performance Assessment in Immersive Mixed and Virtual Environment Systems.
  - Ed Bachelder (Systems technology Inc., US): Helicopter Air Crew Training using Fused Reality.
  - Brian F. Goldiez (University of central Florida, Institute for Simulation and Training, US): Human Performance Assessment when using Augmented Reality for Navigation.
  - Sheila Jaszlics (Pathfinder Systems Inc., US): The DARTS Augmented Reality System.
  - Matthew Franklin (Qinetiq, UK): The Lessons Learned in the application of Augmented Reality.
  - Stephen Ellis (NASA-ARC, US): The User-interface to virtual or augmented environment displays for the Air Traffic Control.
- TER and Keynote Speaker Comments
  - prof Peter Werkhoven (TNO Defense, Security and Safety, The Netherlands).

- prof Paul Milgram (Toronto University, Canada).
- COL James Shufelt (US Army, TRADOC program Integration Office).
- prof Bowen Loftin (Texas A&M University, US).

## 1.4 Attendees

Distribution of attendees across nationality and affiliation:

| Country        | Total     | Defense research institutes | Military | Industry | Academia/<br>Civil res. inst. |
|----------------|-----------|-----------------------------|----------|----------|-------------------------------|
| Canada         | 3         |                             | 1        | 1        | 1                             |
| Denmark        | 1         | 1                           |          |          |                               |
| France         | 1         | 1                           |          |          |                               |
| Germany        | 3         | 2                           |          | 1        |                               |
| Netherlands    | 6         |                             |          | 1        | 5                             |
| Sweden         | 2         | 2                           |          |          |                               |
| United Kingdom | 5         | 3                           |          |          | 2                             |
| USA            | 20        | 9                           | 3        | 3        | 5                             |
| <b>Total</b>   | <b>41</b> | <b>18</b>                   | <b>4</b> | <b>6</b> | <b>13</b>                     |

## 2.0 TECHNICAL-SCIENTIFIC SITUATION OF MILITARY VR APPLICATIONS

### 2.1 Introduction

#### Technological developments

- We see a rise of mixed reality (Milgram) technology. With current technology real and virtual worlds can be mixed. The amount of virtual varies from seeing a virtual bird in your real environment to seeing your real hand in a virtual environment. In the first example only the bird has to be modeled. In the second the complete environment. More complex examples include virtual in real in virtual. Milgram presented a theoretical framework to categorize various forms of mixed reality. From a technical point of view three dimensions can be distinguished: virtual versus real, ego-centricity versus exo-centricity and display congruency. It would be interesting to include social dimensions and other modalities than visual.
- Industry claims that robust Augmented Reality (AR) - representing virtual entities in real environments - is technically feasible (Jaszlics). Furthermore, the AR community is supposed to be “big enough” to increase Technology Readiness level (TRL) and that robust AR is technically feasible (Jaszlics). Wireless stereoscopic networked AR demonstration systems are available (e.g. DARTS system). However, some technological challenges with respect to tracking and occlusion are still remaining. Accurate tracking of the body parts of a soldier in the open field is still years away (Ellis). But we can start looking at applications that don’t need this accuracy or applications in instrumented environments. The ability to occlude parts of the real world that are covered by virtual elements generally still relies on immature technology such as real time 3D reconstruction of the real world and filtering the real world (video

merging or occlusion displays). Furthermore the resolution of (see-through) head mounted display is generally not high enough, for example for AR training of Forward Air Controllers (Franklin). Research into the visual requirements for augmented reality displays for the airport tower has shown that virtual information that occludes the real world may leave out currently used dynamic visual cues that provide lead information used for spacing and sequencing during air traffic management tasks (Ellis). This warning probably has a more general scope.

- In controlled conditions (e.g. cockpits and helicopter training) the concept of fused reality may be an alternative for real time 3D reconstruction of the real world. Fused reality makes use of live video capture and VR merged by chroma-key (magenta) and luma-key technology allowing real objects to move in virtual space. For example in helicopter training it eliminates the need for expensive computer models (Bachelder).
- The value of 3D sound in virtual training generally seems to be underestimated. For example, in the case of forward air control 3D sound can compensate for low resolution displays: we hear the plane before we see it (Franklin).
- AR applications are starting to look at embedded training of team operations. The Battlefield Augmented Reality System (BARS) support dismounted soldiers in room clearing operations. The information provided through head mounted displays changes on criticality and need. Voice and gesture commands can be used to interact with the system. The research focus is now on multiple users and team performance. The use of head-mounted displays is still cumbersome and limits human communication.
- Training in mixed reality may have specific effects on realism, presence, affective appraisal, etc. This poses high demands on cognitive performance tests. Test batteries are needed to assess cognitive performance in mixed reality. A test battery to assess attention, spatial ability, memory, reasoning abilities will be completed in 2007 (pair).
- It has become clear from many discussions on application development that application developers move away from high-end high-fidelity simulators towards low-end simulation. On one hand head mounted displays are still cumbersome and high-end simulators are still costly. On the other hand many training tasks turn out not to rely on realism and can be done using powerful commercial off-the-shelf-game engines (Stone). It must be noted however, that high-end simulators (CAVE, motion platforms) are still required for high-fidelity skill training including eye-hand coordination tasks (e.g. surgery, flight simulation) and multi-user spatial awareness tasks (e.g. room clearing with teams). We always need to go back to “what are the training tasks?”. High fidelity isn’t always the answer. We need to design to optimize training for specific tasks (Brooks).
- Interface technology has not made much progress. The workshop has not revealed any innovations in this field. This is remarkable because a strong recommendation of a NATO workshop in 2000 discussed the need to improve the quality of interfaces with VR. Tracking is still a problem, head-mounted displays are still cumbersome, 3D audio is not used much, force feedback is still in its infancy. Although tactile displays are available for the torso we haven’t seen applications that make use of it. Requirements generators and hardware developers still express the need for intuitive interfaces allowing “train as you fight” simulations. In particular there is a need for improved ergonomic design of mobile AR applications for hands free multimodal interfaces (Bachelder).

### Scientific disciplines involved

- Since the recognition of the importance of intuitive man-machine interaction and intelligent system adaptation to human conditions, simulator engineers have involved psychologists and biologists to improve human performance capabilities within these systems.

- Today we see the need for more disciplines to be included in development of effective AMVE technologies. The research field of simulation deals with modeling (virtual and constructive) worlds, objects and behavior, scenario generation, training methods, multi-sensory interfaces and didactic concepts but also with drama, style and emotions (the gaming element). These components have only had limited application to AMVE applications. But this is why, for example, screenwriters now collaborate with the U.S. intelligence community on "war gaming" and why Paramount Digital Entertainment collaborates with the US Department of Defense on "crisis-management simulation". While it has been claimed that these components have substantial impact on user experience, learning and training transfer, there is only limited research to backup the claims. So, the creative disciplines and liberal arts are beginning to be involved in serious simulation.
- With the introduction of new doctrine and networked (joint and combined) command and control capabilities (NEC) new requirements for the use of AMVE technologies are being developed.
  - We need to cope with a deluge of data and information overload at all levels (tactical, operational and strategic) (Alexander). How will information be "funneled" to the appropriate user? How will information be filtered according to classification and sensitivity to ensure it gets to the right people at the right time and in the right format? Obviously other dimensions than technology become important such as culture, organization, leadership, etc.
  - There is a need for a theoretical framework and predictive models on the complex social and organizational dimensions as a direct consequence of the potential of dynamic task allocation, common operational pictures, commanders talking directly to soldiers and aircrew, etc. There are no sufficient theoretical frameworks to model such complex socio-technical systems. First socio-technical systems that should help leaders to measure monitor and manage are being developed (Freeman) but not yet evaluated.
  - There is a gap in knowledge on how quickly we can learn and adapt to the use of new technologies. How well do people learn in highly dynamic structures? Decisions may get easier but actions may get harder.
  - Scale and complicity drive us towards concept development and experimentation environments with an important role of VR for creating large scale distributed multi-user virtual environments including real and virtual humans, sensors and systems and complex decision structures and dependencies.
- Conclusion: New disciplines must urgently get involved: creative disciplines (scenario and gaming elements), social disciplines (dimensions of socio-technical systems), organizational disciplines (mechanisms and mathematics of self organizing networks).

### **Evolved application fields**

#### **Command and control:**

- Current virtual command and control training systems generally just provide monitoring functionality and lack sufficient feedback and instructional mechanisms (Lussier). It is crucial to include feedback mechanisms and to be able to measure thinking skills and judgments of tactical situations.
- Network enabled command and control deals with dynamic roles and functions, less well defined context for decision making, real time information sharing and a global scale of operations. Central in network enabled command and control is to ability to share relevant information across networks at the right time and in the right form. Although technology currently enables common operational pictures (shared information), it is still a challenge to create common mental models (shared situation



## Technical Evaluation Report

---

awareness). Tolk pointed out that progress in this field relies more on cultural factors (e.g. the willingness to share information, trusting others who are at a distance and allowing for misinterpretations due to cultural differences) than on technology. Further, progress relies on dealing with organizational issues rather than technological ones.

- Challenges for the use of network enabled capabilities (NEC) are the dynamic reallocation of functions during NEC-operations, and tools for supporting multiple command levels (van Veen). When experimenting with Networked Enabled command and control (C2) concepts in simulated worlds it must be possible to vary these aspects and to monitor behavior and performance. The human factors community currently lacks a theoretical framework and predictive models for designing NEC-concepts in laboratories or test beds. . Simulated worlds provide experimentation environments for exploring concepts and development processes. Advanced simulated test beds facilitate the translation of operational needs into new concepts and produce new research questions. Test beds also provide a means to try out new technological innovations to evolve further new concepts and capabilities.
- Public sources such as “Google Earth” have become useful for creating simulated training environments for urban operations (Stanton).

### Tele-operations:

- High fidelity virtual training environments for tele-operations making use of head-mounted displays have not always brought the success expected. Stone opined that early VR technology ‘failed to deliver’. Low-fidelity gaming environments may provide a new promise. Stone used various commercial game engines and experiments favoring a “quick and dirty” approach to human factors research. This approach relies on high frequency short cyclic concept development in which the quality of man-machine interface is implicit and develops in an evolutionary manner. This seems to be the way the commercial gaming world works. However, it should be noted that the game industry has been successful in adopting many of the research results that have come from thorough academic human factors studies. It is a misunderstanding that evolutionary processes are sufficient by themselves and that funding of n academic human factors studies is a poor investment. For example, within some communities high-fidelity systems are still thought to be essential for effective training transfer of perceptual-motor skills (flying, surgery, etc.) when some recent research has indicated that this is not necessarily the case.
- Given our current technology, fully autonomous robotic systems do not seem to be the right approach.. Experiments (van Erp) have shown that human intelligence is still needed and that the operator must be kept in the loop facilitating some sort of tele-presence. The use of HMDs has not been shown to be successful for tele-presence. Attention has shifted towards BOOM-displays. It should be noted that many experimental results cannot be generalized but only hold for the specific design tested.
- Having a human in the loop does not mean that human can necessarily control everything simultaneously. Successful tele-operations must allow for variable and task dependent autonomy (Stanton).
- Alternatives to tele-presence environments for remote control are declarative user interfaces (Trouvain). Specialists operate robots but commanders must specify navigational and manipulation tasks at a higher and more overall task objective oriented level. This may be an advantage for operating swarms of robots in which tele-presence at multiple locations becomes impossible.

**Vehicle simulation:**

- An interesting application of VR in the field of vehicle simulation is assembly and maintenance training. These applications require intuitive manipulation techniques for object handling, such as virtual hand control. The state of the art of existing interface technologies are still far from meeting functional requirements (Vogelmeier). We still have to work with data gloves, head-mounted displays inaccurate tracking devices and rudimentary force feedback systems. No interaction method can generally be applied. Given the limitations of current technology we have to fall back to task and subtask specific interface designs. For many purposes, real mockups are still the best way to go. There is an urgent need to explore new ways of interfacing with virtual worlds, for example brain machine interaction.
- An important aspect of vehicle simulation is motion cuing, the simulation of forces that a vehicle exerts on the user. In particular, for virtual training motion, cuing may be of crucial importance for training transfer. Evidence for this, however, is sparse. A very advanced experimental motion platform (Desdemona) with all degrees of freedom and the option of sustained 3G (max) is currently being built at TNO in the Netherlands (de Graaf). It will be used for research regarding the characteristics of human motion senses and for studying the added value of motion cuing for various driving and flight simulations. For the study of joint mission training requirements it has been linked to real F16 cockpits, C2 facilities and tele-presence control systems.
- Fully virtual training environments seem to no longer meet the functional requirements for vehicle simulation. Furthermore, head mounted displays have been shown to destroy communication between crew members. Consequently a mix of live, virtual & constructive environments (LVC) are being explored for the evaluation of future armored vehicles (Espenant). LVC enables rapid prototyping of vehicles and can be used to assess future technologies that are currently planned. Unfortunately, objective performance measures to determine the effectiveness of these new simulation concepts are still lacking.

**Dismounted soldier simulation:**

- The dynamics of real missions has not yet been sufficiently captured in dismounted virtual simulators. Although technology is not rigorous enough for effective simulations of many dismounted tasks, the main causes of limited support for the development and adoption of training simulators for dismounted soldiers are cultural (Jones). Leaders want to train in real environments, soldiers want to “go out and get cold”. It is simply not the same in a simulator. Further research should reveal to what extent exciting scenarios, new forms of role playing and the “x-factors” from the gaming industry can attract game savvy soldiers into virtual simulators. Experiments made clear that game playing experience has implications for the motivation of trainees and the effectiveness of training (Knerr). The next generation trainees are gamers who don’t like games that have been designed for training (not enough fun). Currently a big gap exists between gaming and training applications. If tomorrow’s military are experienced gamers, will training solutions that use game technology be sufficiently engaging for training purposes?
- Formerly, human factors experts thought they knew better what was good for the user than the user did. Nowadays users are heavily involved in all phases of the evolutionary development process of successful training simulators. It is important to let training systems adapt organically and to evaluate on the fly (Sadagic). The combination of many users and short design cycles provides the feedback necessary to design and develop effective training simulators.
- We form cohesive teams of soldiers by letting them share experiences and stories. VR is a potentially powerful training tool to support these processes (Brooks). An important question, however, is how to

## Technical Evaluation Report

---

built *cost-effective* training systems? An approach proposed by Brooks is to first built effective systems and than cost reduce, not the other way around. The challenges for the coming years are to bring team members in one space. How to provide personal displays without head-Mounted Displays? How to track each of the members (diagnostics) and how to built in “pinball scores” to make the training attractive are questions that need to be answered. A success factor is to involve users from the start to ensure successful early adoption of the training system. Technological challenges are rapid and cheap scenario generation, model acquisition by laser and video and scenario capture by computer vision.

- Dismounted soldier simulators are in urgent need of intuitive interfaces for navigating the virtual world. A good example of human factors engineering has led to an innovative Sony game console based navigation interface (Templeman) that matches the natural motion of soldiers in the field. High-fidelity navigation, however, remains an issue and requires the combination of real movements in virtual environments which needs further research.
- Mission rehearsal is a subset of training and may require less fidelity than training. Simulation has also been set up for pilot selection and is considered a part of tests for promotion. In general the emphasis on dismounted soldier training is on cognitive skills. For this purpose, low-end simulations and game use are on the rise.

Emerging applications fields:

- VR for selection of personnel (suggestion Milgram).
- VR for medical assessment, cognitive tests, and treatment (Pair).
- Gaming environments for recruitment (US Army game).

### Requirements perspective

- The US Army TRADOC Program Integration Office, Virtual (TPIO,Virtual) (Shufelt) has developed a clear vision and strategy on future combat training systems. Key for future virtual training systems will be that they are: combined arms, full spectrum, embedded and all terrain. In 2025 approximately 10% of the total force should be able to train according to these principles. We will see fading boundaries between training and operations. Embedded training devices will also serve to realize operational networked enabled capabilities for net centric warfare. The most important technology trends identified are the rise of joint experimentation networks, the use of (commercial) game technology, the development of virtual humans and augmented reality displays. Requirements for these developments are interoperability, “plug and train” functionality, the availability of terrain databases within 48 hours, multilevel security and cognitive models for virtual instructors.
- The US Army’s PEO,STRI (Riggins) wants to strengthen expeditionary capabilities by developing trainings systems with a highly modular composition. The strengths of current training systems are mobility and tactical and spatial fidelity. Areas for improvement are virtual instructor functionality, train as you fight functionality (combinations of live and constructive) and mission rehearsal functionality. Progress is not solely dependent on technology development. It has been recognized that all lines of development should progress in balance: doctrine, materiel, leadership, facilities, operations and personnel. The focus will be on collective (not just individual) training functionality.

### **Application development approach**

- Much of the conclusions of human factors research on the effectiveness of VR and mixed reality are still in terms of “don’t know” and “depends on”. This illustrates the complexity of the research questions. Human factors knowledge traditionally focused more on individual tasks in controlled conditions. There are insufficient theoretical frameworks and predictive models for more complex socio-technical systems and a systems of systems approach. For training situations that deal with collective performance most human factors questions are still unanswered because cognitive models of group behavior are lacking (Sadagic and Darken).
- In order to progress on research questions more explorative concept development and experimentation methods are being developed. It is a challenge to find new methods for structuring concept development and experimentation such that existing human factors knowledge is brought optimally into the design and such that we do not arrive at suboptimal solutions.

## **2.2 Bottlenecks and opportunities**

Based on the observations listed in section 2.1 we summarize the following opportunities:

- Agendas and strategies of defense organizations world wide reveal a high priority for the realization of embedded virtual training capabilities to strengthen the ability to train while deployed to locations around the world. The following key technology trends have been identified: joint experimentation networks, the use of (commercial) game technology, the development of virtual humans and augmented reality displays. Embedded training devices will also serve to realize operational networked enabled capabilities for net centric warfare. The focus will be on collective (not just individual) training functionality.
- Emerging applications fields are VR for selection of personnel, VR for medical assessment, cognitive tests, and treatment and gaming environments for recruitment.

Section 2.1 also showed the following bottlenecks and challenges:

- Mixed reality (merging of real and virtual worlds) is promising but the technology for tracking body positions in the open field and real time real world modeling are still immature.
- Validated test batteries are needed to assess cognitive performance in mixed reality (attention, spatial ability, memory, reasoning abilities).
- Interface technology has not made much progress in the last six years (head-mounted displays are still cumbersome and destroy communication, force feedback is still in its infant years). There is a need for improved ergonomic design of mobile AR applications and hands free, intuitive, multi-modal interfaces allowing “train as you fight” simulations.
- For training situations that deal with large scale collective performance in networked operations most human factors questions are still unanswered because predictive cognitive models of group behavior are lacking. Progress urgently requires the involvement of social disciplines (dimensions of socio-technical systems, cultural factors), organizational disciplines (mechanisms and mathematics of self organizing networks) and creative disciplines (scenario and gaming elements).
- The main causes of limited use of the potential of training simulators for dismounted soldiers are cultural: leaders want to train in real environments and soldiers want to “go out and get cold”. The case for training in virtual worlds to prepare for training in live environments has yet to be effectively made.

## Technical Evaluation Report

---

- Current training systems usually meet the immediate training needs but are not sufficiently designed to allow for flexibility and evolution.
- The development of many virtual training applications has not yet balanced all lines of development: doctrine, materiel, leadership, facilities, operations and personnel.
- More interchange of ideas is needed between research community, system developers, requirement people and military users, especially in C2/NEC. Often there is good evidence & data to support a given decision but requirement people supporting another decision may not be aware of it.
- Services need to communicate better resulting in effective transfer of knowledge, lessons learned, etc.
- There are no funds for longitudinal studies. Longitudinal studies are essential for measuring long term adaptation of users to new technology.
- Human factors conclusions are often design specific. There is a strong need for more generic guide lines to guide developers and optimize system design.

### 2.3 Recommended actions

We have come to the following recommendations:

- Create fully integrated joint Concept Development and Experimentation facilities for the development and training of Networked Enabled Capabilities (dynamic reallocation of functions, switching micro/macro command levels, trust in command at distance, etc.).
- Focus research on:
  - Theoretical framework on socio-technical systems and predictive cognitive models for the effective structuring and evaluating of Concept Development and Experimentation (CDE) processes with a focus on collective performance,
  - Virtual characters and virtual instructors,
  - Non-obtrusive intuitive multimodal (brain machine) interfaces for hands free navigation and manipulation, allowing (non-verbal) team interactions and “train like you fight”,
  - Rapid scenario generation and scenario capture,
  - Non obtrusive mixed (augmented) reality displays,
  - Tracking technology for the open field,
  - Validated test batteries to assess cognitive performance in mixed reality (attention, spatial ability, memory, reasoning abilities),
  - Generic human factors guidelines versus design specific results.
- Create budgets for longitudinal studies on adaptation of users to new technology,
- Involve organizational, social and cultural disciplines,
- Stimulate dual use of commercial gaming technology and military simulation technology.
- Design training systems to allow for flexibility and evolution.
- Balanced all lines of system development: doctrine, materiel, leadership, facilities, operations and personnel.

- Better organize the dialog between the research communities, system developers, requirement people and military users, especially in the field of C2 and NEC.
- Better organize the dialog between services resulting in a effective transfer of knowledge and lessons learned.

The enthusiasm of the workshop attendees and the evident willingness to share ideas and to discuss their findings provides a promising base for working on these recommendations.

Please note that recommendations below generated by NATO study group HFM-021 in 2000 are still unfulfilled needs today:

- The military should develop a vision on the use of VR technology and more clearly specify their needs.
- Industry should work on standardization and should substantially bring human factors into their design and development processes.
- Academia and research institutes should coordinate and accelerate their long-term research efforts to focus on natural interfaces (innovative metaphors) and on how to model human and object behavior.
- In the short term academia should focus on human factors metrics and metrics for team and collective performance (cognition, communication), and a standard evaluation methodology.
- In general, better coordination between military organizations, industry and academia is necessary in order to identify gaps in current knowledge and coordinate research.

### **3.0 CONCLUSIONS**

The workshop “Virtual media for Military Applications” uniquely has brought together prominent people from academia, industry and the military. Workshop attendees enthusiastically and knowledgeably:

- exchanged operational requirements and on-going research in the field of augmented, mixed and virtual reality technology (AMVE) for military applications,
- identified success factors and bottlenecks for implementation, and
- have made recommendations for future research agenda’s, methodological approaches and organizational issues.

The main conclusions are:

- For training situations that deal with collective performance most human factors questions are still unanswered because predictive cognitive models of group behavior are lacking. Serious research budgets for longitudinal studies, fully integrated concept development and experimentation facilities and the involvement of social, organizational and creative disciplines are necessary to find the answers.
- Developers of virtual media applications make significant use of public data bases and commercial off the shelf gaming technology. Gaming technology evolves quickly with extremely short cycles and massive numbers of users. As such, it generates implicit human factors knowledge together with technological advances which seems to put military training system developers and the traditional human factors community at the “tail” of the gaming community. Dual use of gaming and military



## Technical Evaluation Report

---

simulation technology should be further stimulated. Military researchers should not try to keep pace with gaming technology but rather work to adapt technology advances to unique military applications.

- Exciting pushes are seen into “new” territories such as serious gaming, unmanned vehicles and robotics (tele-presence), dismounted training capabilities and emerging applications in the field of personnel selection and recruitment and medical treatment.
- The dialog between the research communities, system developers, requirement people and military users and between services themselves has to be improved for a more effective transfer of knowledge and lessons learned.

### Future Meetings

In 2000, HFM 121 held a workshop to look at the applications of virtual technologies to military use. In many respects HFM-136 was a re-look at an expanded realm in which AMVE technologies are being used by the military. Six years have gone by but as noted above much work still needs to be done to provide NATO militaries with AMVE systems that are usable by soldiers, sailors and airman and effective for the purpose they were designed.

The direction of change has taken some unanticipated turns since 2000. Full scale VR does not seem as likely a solution as once thought. Game technology, augmented reality, and embedded capability seem to be the direction requirements and technology is going. The need to ensure that human considerations are taken into account is a continuing requirement. There will need to be a follow on to this workshop that explores in more detail the current trends as noted in this TER. In particular the embedding of training in weapon systems is a topic that will include considerations of live, virtual and constructive simulation and will be worthy of further study.